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1. Your reference	sps.2843.uk.dkach
2. Patent application number *(The Patent Office will fill in this part)*	0307724.5 — ~~03APR03 E797582-1 010002~~ P01/7700 0.00-0307724.5
3. Full name, address and postcode of the or of each applicant *(underline all surnames)*	Specialised Petroleum Services Group Limited Wellbore Completion Services Arnhall Business Park Westhill ABERDEEN AB32 6TQ
Patents ADP number *(if you know it)*	8460784001
If the applicant is a corporate body, give the country/state of its incorporation	United Kingdom
4. Title of the invention	Improved Mechanism for Actuation of a Downhole Tool
5. Name of your agent *(if you have one)* "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	Kennedys Patent Agency Limited Queens House, Floor 5 29 St Vincent Place GLASGOW G1 2DT
Patents ADP number *(if you know it)*	08058240002

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number	Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application	Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:* *a) any applicant named in part 3 is not an inventor, or* *b) there is an inventor who is not named as an applicant, or* *c) any named applicant is a corporate body.* *See note (d))*	Yes

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9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form	--
Description	18
Claim *(s)*	--
Abstract	--
Drawing *(s)*	2

10. If you are also filing any of the following, state how many against each item.

Priority documents	--
Translations of priority documents	--
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	--
Request for preliminary examination and search *(Patents Form 9/77)*	--
Request for substantive examination *(Patents Form 10/77)*	--
Any other documents *(please specify)*	--

11. I/We request the grant of a patent on the basis of this application.

Signature KENNEDYS PATENT AGENCY LIMITED Date 03.04.2003

12. Name and daytime telephone number of person to contact in the United Kingdom David Kennedy - 0141 226 6826

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Improved Mechanism for Actuation of a Downhole Tool

The present invention relates to downhole tools as used in the oil and gas industry and in particular, though not exclusively, to a mechanism for moving a sleeve in a downhole tool by passing a ball along a helical groove in the sleeve.

While many downhole tools operate continuously through a well bore e.g. scrapers and brushes as disclosed in US 6,227,291, it is more desirable to provide a tool which performs a function only when it has reached a preferred location within a well bore. An example of such a tool would be a circulation tool as disclosed in WO 02/061236. The tool provides a cleaning action on the walls of the casing or lining of the well bore. The cleaning action is only required after the casing has been brushed or scraped and thus the tool is designed to be selectively actuated in the well bore. Such tools provide the advantage of allowing an operator to mount a number of tools on a single work string and operate them individually on a single trip in to the well bore. This saves significant time in making the well operational.

Tools which are selectively actuable in a well bore commonly operate by having an element which can be moved relative to the tool when in the well bore. In the circulation tool of WO 02/061236, the element is a sleeve located in the cylindrical body of the tool. When run in the well, the sleeve is held in a first position by one or more shear screws. To actuate the tool, a drop ball is released from the surface of the well through the work string. On reaching the sleeve, the ball blocks the flow of fluid through the tool and consequently pressure builds up until the shear screws shear and the sleeve is forced downwards. The movement of the sleeve is then stopped when a lower ledge of the sleeve contacts a shoulder on the internal surface of the tool body.

Such tools have a number of disadvantages. The tools are generally limited to one actuable movement. If two sleeves are incorporated to overcome this, the shear screws of the second sleeve can operate prematurely under the shock created to shear the shear screws of the first sleeve. Additionally, the reduced bore diameter of the lower part also effects the flow rate achievable through the tool.

One tool which has been developed to operate repeatedly is that disclosed in US 4,889,199. This tool comprises a tubular body having a radial port into which is located a sleeve having a matching radial port. The sleeve is slidably mounted and its action controlled from a deformable drop ball biasing the sleeve against a spring. Initially the spring biases the sleeve to a closed position in which the ports are misaligned. The drop ball causes the sleeve to move to a position where the ports

align due to a build up of pressure behind the ball, and fluid is discharged radially through the ports. A small steel ball is then dropped into the tool which seals the radial ports and the consequential pressure build up extrudes the deformable ball through the ball seat. The steel ball will drop with the deformable ball and both are retained in a ball catcher at the base of the tool. When the balls drop together the spring biases the sleeve back to the closed position and the tool can be operated repeatedly.

A disadvantage of this tool is that it requires both a deformable ball and a smaller metal ball to operate. Care must then be taken to ensure the balls are dropped in the correct order. The smaller metal ball must lodge in the second, radial, outlet in order to stop flow and thus the tool is restricted to having a single radial port. This limits the amount of cleaning which can be performed. Yet further is a disadvantage in that use of a rubber or deformable ball is unreliable as the material can break up or wear within the well bore.

It is an object of the present invention to provide an actuation mechanism for a downhole tool which obviates or mitigates at least some of the disadvantages of the prior art.

It is a further object of at least one embodiment of the present invention to provide an actuation mechanism to move a sleeve within a downhole tool.

It is a yet further object of at least one embodiment of the present invention to provide an actuation mechanism

for use in a downhole tool which is re-settable to allow the tool to operate in a cyclic manner.

It is yet further object of at least one embodiment of the present invention to provide a circulation tool which can be operated repeatedly using a single ball.

According to a first aspect of the present invention there is provided an actuation mechanism for a downhole tool, the mechanism comprising a substantially cylindrical body having a central bore running axially therethrough, a sleeve located within the bore, the sleeve including a helical channel on an inner surface, mechanical biasing means located between the sleeve and the body to bias the sleeve in a first direction and a ball, sized to run in the helical channel in a reverse direction to prevent a majority of fluid flow through the sleeve and cause the sleeve to move in the reverse direction relative to the body.

When the ball is dropped in the body, fluid will drive the ball into the channel and into the helical path. As the ball is sized for the channel it will block the majority of the fluid path through the tool and consequently pressure will build up on the ball. This pressure will be sufficient to move the ball and sleeve together against the spring and force the sleeve in the reverse direction. The movement of the sleeve actuates the tool. On release of the ball from the channel the sleeve is biased in the first direction back to its original position.

Preferably the mechanical bias is a strong spring. The spring may be helical, conical or the like. A strong string will prevent the sleeve moving in the reverse direction by fluid flow in the central bore.

Preferably the helical channel has curved walls. This will prevent damage to the ball. Preferably also the ball is sized to provide a fluid by-pass around the ball when in the channel. The ensures a positive pressure is maintained behind the ball and prevents chattering of the ball in the channel.

The helical channel may be considered as a screw thread. Thus the channel has a left hand thread so that the ball travels in the opposite direction to the rotation of the tool on a work string. Preferably a pitch of the thread is greater than or equal to a diameter of the ball.

Preferably the ball is spherical. More preferably the ball is of a non-pliable material and thus cannot deform. Advantageously the ball is made of steel.

Preferably also the sleeve includes a conical surface at an entrance to the channel. This funnels the ball into the channel and ensures it travels into the helical path.

According to a second aspect of the present invention there is provided a downhole tool for circulating fluid in a borehole, the tool comprising a substantially cylindrical body having a central bore running axially therethrough, the body including at least one first port arranged substantially transversely to the central bore, a sleeve located within the bore, the sleeve including at

least one second port arranged transversely to the central bore for discharging fluid from the central bore when the first and second ports are aligned and mechanical biasing means located between the sleeve and the body to bias the sleeve in a first direction at which the ports are misaligned, wherein at least a portion of the sleeve includes a helical channel on an inner surface thereof, and the tool further includes at least one ball, the ball being sized to run in the helical channel in a reverse direction to prevent a majority of fluid flow through the sleeve and cause the sleeve to move in the reverse direction relative to the body so that the ports come into alignment.

Preferably the mechanical bias is a strong spring. The spring may be helical, conical or the like. A strong string will prevent the sleeve moving in the reverse direction by fluid flow in the central bore.

Preferably the helical channel has curved walls. This will prevent damage to the ball. Preferably also the ball is sized to provide a fluid by-pass around the ball when in the channel. The ensures a positive pressure is maintained behind the ball and prevents chattering of the ball in the channel.

The helical channel may be considered as a screw thread. Thus the channel has a left hand thread so that the ball travels in the opposite direction to the rotation of the tool on a work string. Preferably a pitch of the thread is greater than or equal to a diameter of the ball.

Preferably the ball is spherical. More preferably the ball is of a non-pliable material and thus cannot deform. Advantageously the ball is made of steel.

Preferably also the sleeve includes a conical surface at an entrance to the channel. This funnels the ball into the channel and ensures it travels into the helical path.

Preferably the tool further comprises engagement means to control relative movement between the sleeve means and the body. Preferably also the mechanical bias biases the sleeve against the engagement means.

Preferably also the tool includes ball collecting means. The ball collecting means may be an element located in the casing means to prevent passage of the ball through the tool, but allowing passage of fluid through the tool.

Preferably said first and second ports are located substantially perpendicular to a longitudinal axis through the tool. More preferably there are a plurality of said first and said second ports. Advantageously there are three or more said first and said second outlets. Preferably also said first and said second outlets are spaced equidistantly around the body and the sleeve respectively.

Preferably said engagement means comprises at least one index pin located in a profiled groove. Preferably the at least one index pin is located on the body and the profiled groove is located on an outer surface of the sleeve. In this way, an index sleeve is produced with the groove determining the relative position of the sleeve to

the body. Advantageously the groove extends circumferentially around the sleeve, thus the tool can be continuously cycled.

Preferably also the spring is located in a chamber created between the sleeve and the body. Advantageously the chamber includes an exhaust port such that fluid can enter and be dispelled from the chamber by relative movement of the sleeve and the body.

According to a third aspect of the present there is provided a method of actuating a tool in a borehole, the method comprising the steps;

(a) inserting in a work string a tool including an actuating mechanism according to the first aspect;
(b) running the work string and tool into a borehole, with the tool in a first operating position;
(c) dropping a ball into the work string such that the ball travels along the helical channel and by virtue of an increase in pressure on the ball, forcing the sleeve to move and switching the tool to a second operating position; and
(d) on exit of the ball from the channel, returning the tool to the first operating position as the mechanical bias acts on the sleeve.

According to a fourth aspect of the present invention there is provided a method of circulating fluid in a borehole, the method comprising the steps:

(a) inserting in a work string a tool including an actuating mechanism according to the second aspect;

(b) running the work string and tool into a borehole, with the tool in a closed position wherein the ports are misaligned and fluid flows through the central bore;

(c) dropping a ball into the work string such that the ball travels along the helical channel and by virtue of an increase in pressure on the ball, forcing the sleeve to move and switching the tool to an open position wherein the ports are aligned;

(d) discharging fluid from the ports; and

(e) on exit of the ball from the channel, returning the tool to the closed position as the mechanical bias acts on the sleeve.

Preferably the method further includes the steps of:

(f) dropping a second ball, identical to the first ball, into the work string such that the second ball travels along the helical channel and by virtue of an increase in pressure on the ball, forcing the sleeve to move and switching the tool to an open position wherein the ports are aligned;

(g) discharging fluid from the ports; and

(h) on exit of the ball from the channel, returning the tool to the closed position as the mechanical bias acts on the sleeve.

With the sleeve and back in the first position, the steps (f) to (h) can be repeated any number of times.

Preferably also the method includes the step of catching the dropped balls in the work string.

According to a fifth aspect of the present invention there is provided a method of circulating fluid in a borehole, the method comprising the steps:

(a) inserting in a work string a tool including an actuating mechanism according to the second aspect;
(b) running the work string and tool into a borehole, with the tool in a first position wherein the ports are misaligned and fluid flows through the work string;
(c) dropping a ball into the work string such that the ball travels along the helical channel and by virtue of an increase in pressure on the ball, forcing the sleeve to move into a second position relative to the body wherein the ports are misaligned and fluid flow is through the work string;
(d) on exit of the ball from the channel, moving the tool to a third position by virtue of the mechanical bias acting on the sleeve wherein the ports are aligned and fluid flows through the ports.

Preferably the method further includes the steps of:

(e) dropping a second ball, identical to the first ball, into the work string such that the second ball travels along the helical channel and by virtue of an increase in pressure on the ball, forcing the sleeve to move the second position relative to the casing wherein the first and second ports are

misaligned and fluid flow is through the work string; and

(f) on exit of the ball from the channel, moving the sleeve to the first position by virtue of the mechanical wherein the first and second ports are misaligned and fluid flows through the work string.

With the sleeve and casing back in the first position, the steps (c) to (f) can be repeated any number of times.

Preferably also the method includes the step of catching the dropped balls in the work string.

An embodiment of the present invention will now be described by way of example only with reference to the following Figures, of which:

Figure 1 is a part cross-sectional view of a downhole tool in a first position according to an embodiment of the present invention;

Figure 2 is a part cross-sectional view of the downhole tool of Figure 1 in a second position;

Figure 3 is a part cross-sectional view of the downhole tool of Figure 1 in a third position; and

Figures 4(a)-(c) are schematic illustrations of an index pin positioned in a groove of the tool of Figure 1 for the first, second and third positions respectively.

Reference is initially made to Figure 1 of the drawings which illustrates a downhole tool, generally indicated by

reference numeral 10, in accordance with an embodiment of the present invention. Tool 10 includes a cylindrical body 12 having an upper end 14, a lower end 16 and a cylindrical bore 18 running therethrough. The body 12 has a box section 20 located at the upper end 14 and a pin section 22 located at the lower end 16 for connecting the tool 10 in a work string or drill string (not shown).

The body 12 further includes four radial ports 24 located equidistantly around the body 12. The ports 24 are perpendicular to the bore 18.

Located on an inner surface 26 of the body 12 are two opposing ledges 26, 28 used to limit axial movement of a sleeve 30 located within the body 12. Sleeve 30 is sealed against body 12 by o-rings 31a-d.

Sleeve 30 is an annular body which also includes four radial ports 32 located equidistantly around the sleeve 30. The ports 32 are perpendicular to the bore 18. The ports 32 are of a similar size to the ports 24 in the body 12.

At an upper end 36 of the sleeve 30 is located a conical surface 38 facing the upper end 14 of the tool 10. Downwardly extending from the conical surface is a helical channel 34. The channel 34 comprises a continuous spiral groove, having curved walls 40, which takes the path of a screw thread on the inner surface 39 of the sleeve 30. The handedness of the 'screw thread' is left handed.

Located between the outer surface 44 of the sleeve 30 and the inner surface 46 of the body 12 is a space forming a chamber 48. The upper edge of the chamber is formed from a ledge 50 on the outer surface 44 of the sleeve 30. The lower edge of the chamber 48 is formed from the ledge 28 of the body 12. A strong spring 52 is positioned within the chamber 48 and compressed to bias against the ledge 50 of the sleeve 30. An exhaust port 54 is located through the sleeve 30 at the chamber 48 to allow fluid from the bore 42 to pass in to and out of the chamber 48 as the sleeve 30 is moved relative to the body 12.

Further an engagement mechanism, generally indicated by reference numeral 56, couples the sleeve 30 to the body 12 and controls relative movement there between. Engagement mechanism 56 comprises an index sleeve 58, being a portion of the sleeve 30, and a matching index pin 60 located through the body 12 towards the sleeve 30. Index sleeve 58 includes a profiled groove 62 on the outer surface 44 of the sleeve 30 into which the index pin 60 locates.

Reference is now made to Figure 4 of the drawings which illustrates the groove 62 of the index sleeve 58. The groove 62 extends circumferentially around the sleeve 30 in a continuous path. The groove 62 defines a path having a substantially zig-zag profile to provided axial movement of the sleeve 30 relative to the body 12. Indeed, spring 52 biases the sleeve 30 against the index pin 60. The path includes an extended longitudinal portion 64 at every second upper apex of the zig-zag. Further a stop 66 is located at the apexes of the zig-zags to encourage the index pin 60 to remain at the

apexes and provide a locking function to the tool 10. The stops 66 are in the direction of travel of the pin 60 along the groove 62.

Reference is now made to Figure 2 of the drawings which illustrates the tool 10 of Figure 1, now with a ball 68 located in the bore 42. Like parts to those of Figure 1 have been given the same reference numeral for ease of identification. Ball 68 is sized to travel along the helical channel 34. Ideally the ball 68 is sized to have a diameter less than or equal to the pitch of the screw thread forming the walls 40 of the channel 34. In this way when the ball 68 travels along the channel 34 a by-pass is created between the edge of the ball 68 and the walls 40 of the channel 34. The ball is of a hard material which is non-pliable. Ideally the ball is made of a metal such as steel.

Reference is now made to Figure 3 of the drawings which illustrates the tool 10 of Figure 1, now with the ball 68 exiting the sleeve 30 into the bore 18. Like parts to those of Figures 1 and 2 have been given the same reference numeral for ease of identification. Body 12 includes a pin 70 located into the bore 18. Pin 70 is a ball retainer pin which blocks the passage of the ball 68 through the bore 18. Ball 68 will come to rest at the pin 70 and therefore be retrievable with the tool 10. Pin 70 does not prevent the flow of fluid through the bore 18 and from the tool 10 into the work string below. The pin 70 and the space 72 in the bore 18 immediately above it may be considered as a ball catcher.

In use, tool 10 is connected to a work string using the box section 20 and the pin section 22. As shown in Figures 1 and 4(a), the spring 52 biases the sleeve 30 against the index pin 60 such that the pin 60 is located in the base apex of the groove 62. This is referred to as the first position of the tool 10. In this position, sleeve ports 32 are located above body ports 24, thus preventing fluid flow radially through these ports due to their misalignment. All fluid flow is through bores 18,42 of the tool 10. The tool 10 is then run into a bore hole until it reaches a location where cleaning of the bore hole casing or circulation of the fluid through the tool is required.

Drop ball 68 is then released through the bore of the work string from a surface. Ball 68 travels by fluid pressure to the conical surface 38 at the upper end 36 of the sleeve 30. The ball 68 is funnelled into the helical channel 34 where its progress is arrested. As the ball 68 is now blocking the majority of fluid flow through the bore 42, fluid pressure will build up behind the ball and force the ball along the helical channel 34. Due to the size of the ball a small amount of fluid will be allowed to by-pass the ball 68. This fluid by-pass ensures that a positive pressure is maintained behind the ball 68 so that the ball 68 does not flow towards the upper end 14 of the tool 10 also prevents the ball 68 from 'chattering' in the channel 34. As the ball 68 makes its way along the channel 34 it acts as a temporary flow restrictor allowing sufficient pressure to build up on the ball 68 and sleeve 30 such that they can move in the direction of applied pressure against the bias of the spring. Consequently the sleeve 30 and ball 68 move to a

second position. This position is illustrated in Figure 2 and 4(b). Though the ball 68 at the top of the channel 34 it will be appreciated that this position can be reached with the ball in this position or when the ball 68 has travelled a distance down the channel 34. The spring 52 is compressed into a now smaller chamber 48. Fluid has been expelled from the chamber 48 through the exhaust port 54. The index pin 60 is now located at the top of the longitudinal portion 64 of the groove 62. Consequently the sleeve ports 32 have crossed the body ports 24 and are now located below them. Fluid flow is thus still entirely through the bores 18,42.

On reaching the base of the channel 34, at the sleeve port 32, the ball 68 exits the channel 34 and free falls from this point. The ball 68 travels by fluid pressure until it is stopped by the pin 70 and is held in the space 72. On release of the pressure, spring 52 moves the sleeve 30 against the index pin 60 such that sleeve travels to a third position. The third position is illustrated in Figures 3 and 4(c). Fluid has been drawn into the chamber 48 and this drawing and expelling of fluid provides a hydraulic damping effect on the impact on the pin 60. Index pin 60 is now located in an upper apex of the groove 62 and the ports 24,32 are aligned. In this third position fluid is expelled radially from the tool 10 through the now aligned ports 24,32. The tool 10 is locked in this position by virtue of the stop 66 on the groove 62 which prevents movement of the sleeve 30 for small variations in fluid pressure.

In order to close the ports 24,32, a second ball is dropped from the surface through the work string. The

second ball, and indeed any ball subsequent to this, is identical to the first ball 68. The second ball will travel to the conical surface 38. On the build up of fluid pressure behind the ball 68 it travels along the helical channel 34 and sleeve 30 will move downwards against the bias of the spring 52. Consequently the index pin 60 will be relocated into the next longitudinal groove 64 of the groove 62 and thus the tool is returned to the second position. When the second ball exits the helical channel 34, the pin 60 and sleeve 30 will move relatively back to the first position and the second ball will come to rest by the first ball 68. Effectively the tool is reset and by dropping further balls the tool 10 can be repeatedly cycled in an open and closed manner as often as desired.

It will be appreciated that although the description refers to relative positions as being 'above' and 'below', the tool of the present invention can equally well be used in horizontal or inclined boreholes and is not restricted to vertical boreholes. Additionally the term 'borehole' can be used to refer to an open, cased or lined well bore.

The principal advantage of the present invention is that it provides an actuating mechanism which can be repeatedly operated in a downhole tool. Further the mechanism dispenses with the need for a ball seat having a diameter smaller than the diameter of the drop ball and thus the flow through area of a tool incorporating the mechanism is improved over prior art drop ball actuated tools.

Further an embodiment of the invention advantageously provides a downhole tool for circulating fluid in a borehole which can be repeatedly operated by dropping identical balls through the work string. A further advantage is that the tool can have any number of radial ports to increase the flow area if desired compared with the prior art.

Further as the actuating meachnism is located above the ports, the ports are opened with no flow going across the seals. This effectively saves the seals from excessive wear. An additional advantage is in the ability of the index sleeve to lock the circulating ports in position when aligned. Yet further the entry and exit of fluid in the chamber for the spring advantageously reduces the impact on the index pin via the hydraulic damping effect.

Various modifications may be made to the invention herein described without departing from the scope thereof. For example, two or more index pins could be used to provide increased stability to the tool and distribute the load on the pins. Additional radial ports could be located at longitudinal spacings on the tool to provide radial fluid flow across a larger area when the ports are open. The ports may have varying diameters which may provide a nozzle on the outer surface of the body to increase fluid velocity.

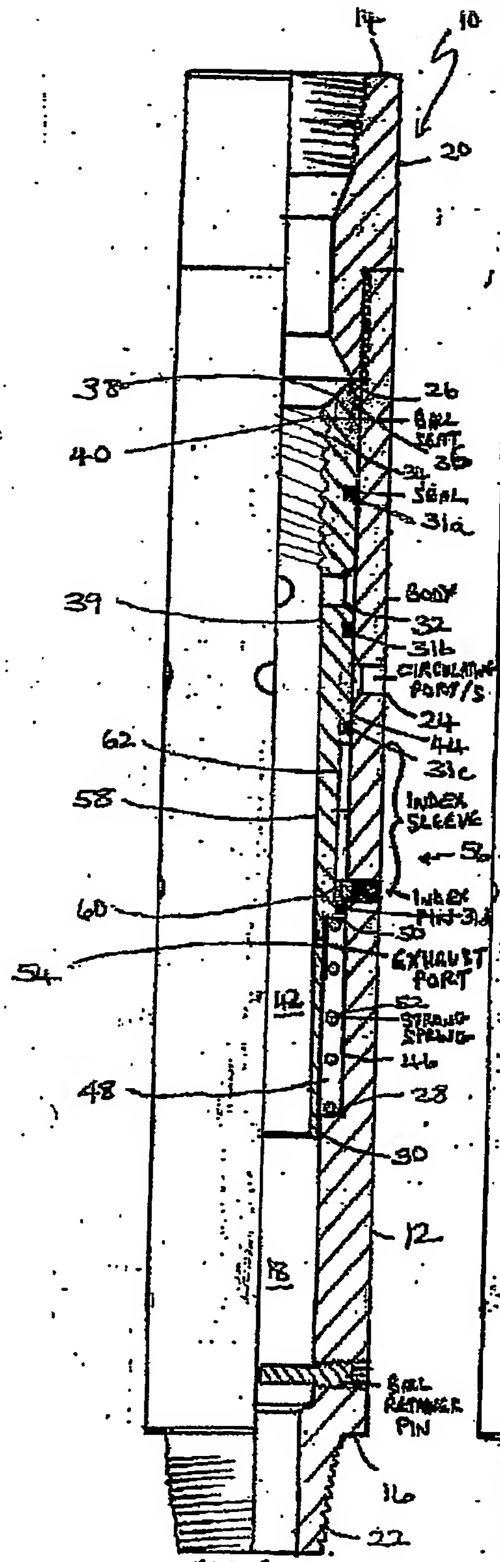


FIG 1

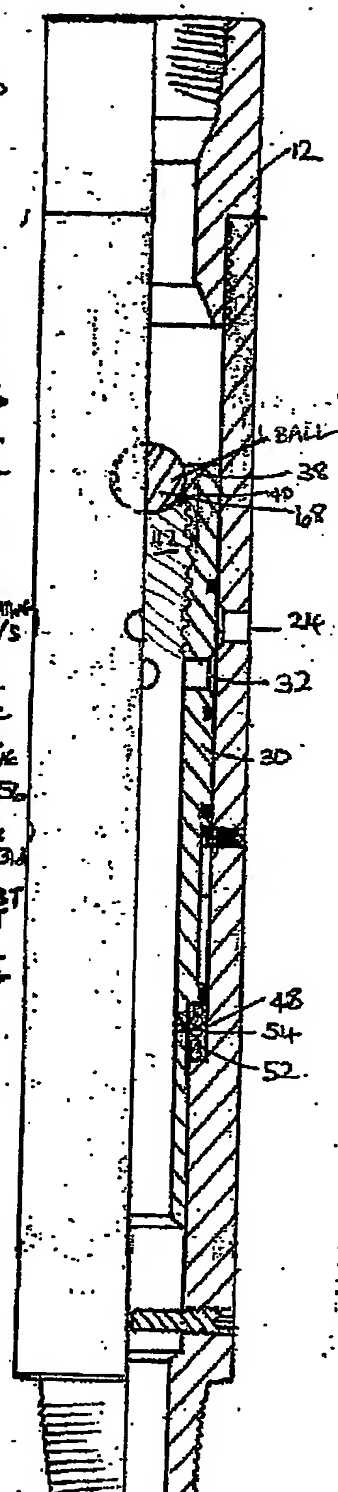


FIG 2

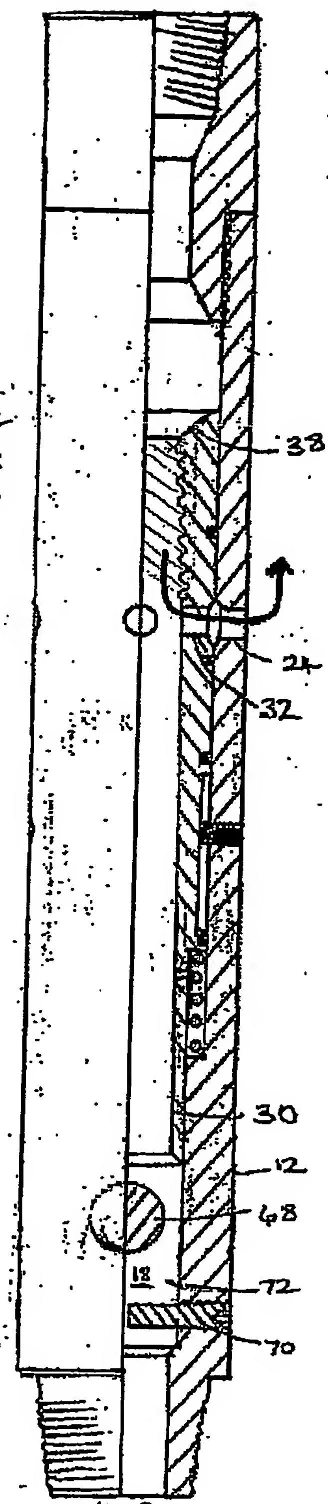
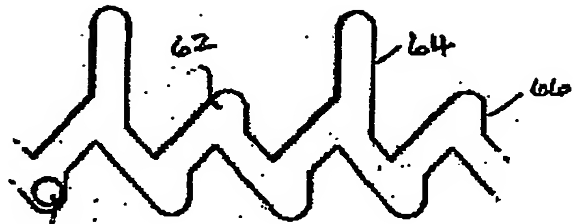
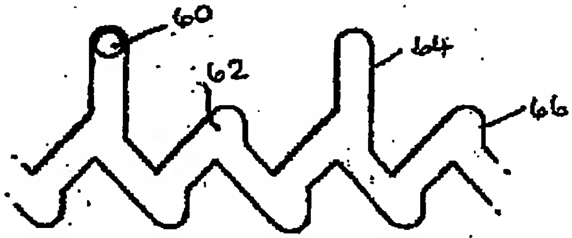


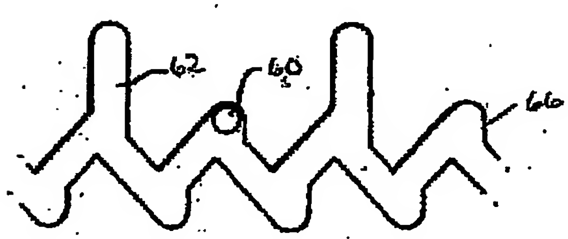
FIG 3



(a)



(b)



(c)

FIG 4

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